Inventory Audit Report
Mackenzie Timber Supply Area

Revised August 1996

A report was released in August 1994 summarizing results and recommendations arising from an inventory audit conducted during 1993 for the Mackenzie Timber Supply Area. It has since been noted that an improper database field was used for some of the height projections, which affected the volume calculations.

The volume figures have been recalculated and are correct as shown in this revised report. The differences are minor, and no changes are necessary to the overall recommendations of the original report.

Introduction

Background

In British Columbia, forest inventories for specific areas are conducted usually every 10 to 30 years, with regular updates between re-inventories to reflect changes in the forest due to growth and depletions.

The question "How accurate is the current inventory?" often arises. To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

The Forest Inventory Program refers to this statistical auditing methodology as an Inventory Audit. The objective of the inventory audit is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stand, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since the area sampled constitutes only a portion of the total forested area in the TSA.

The audits provide information that may be useful to the chief forester during determinations of the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

This report presents the results of an inventory audit conducted in the Mackenzie Timber Supply Area (TSA) in the north-central portion of the Prince George Forest Region. The Mackenzie TSA represents approximately six million hectares of primarily mature lodgepole pine, spruce, and balsam leading types and comprises six public sustained yield units (PSYUs), which were re-inventoried between 1965 and 1982.

The primary objectives of conducting an inventory audit in this area were to validate the timber inventory and to provide baseline information for the pre-inventory assessment process.

Methods

Current inventory

The province is divided into 37 TSAs, which can vary from 200 000 hectares to 13 million hectares. Inventories can be performed on a complete TSA or on a portion of it. Inventories are conducted by first delineating forest stands (polygons) on 1:15 000-scale aerial photographs. A number of photo-interpreted

variables are assessed for each polygon, including species composition, stand height, age, and crown closure. Volume is then estimated indirectly using these photo-interpreted variables and empirical yield models.

To keep the estimates current, inventories are regularly updated to account for forest growth and depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth; field visits, satellite imagery, and aerial photographs may be used to update for depletions.

The inventory audit for the Mackenzie TSA was initially based on a random sample of 50 polygons (audit sample) selected from the target population of mature and immature forest stands. The establishment of the audit sample is described below.

For each of the polygons, the existing photo-interpreted variables, updated from the original inventory, were projected to 1993 and fed into the VDYP model to obtain 1993 estimates of the volume per hectare (inventory volume). The inventory volume estimates were then compared to volume estimates obtained from the audit sample (audit volume).

Audit sample

Forest inventory maps for the Mackenzie TSA, produced between 1965 and 1982, formed the basis for sampling. A stratified random sample of 50 polygons from lodgepole pine, spruce, balsam, and aspen forest types was selected. This report describes the results obtained from 47 polygons. Three polygons were dropped from the analysis because an unacceptable level of bias was introduced during data collection.

Up to three full-measure prism plots, and nine count plots, were established within each of the 50 sample polygons. The plots were located systematically, using a triangular design and a randomly selected start point. For large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 560 full-measure and count plots were established. Field data collection and compilation followed the standard Ministry of Forests cruising and cruise compilation procedures. Utilization limits and merchantability definitions were chosen so that the compiled audit volumes would be comparable to the inventory volumes produced using the VDYP model.

The VDYP model produces net merchantable volumes per hectare, defined as whole-stem volume inside bark of all live trees of dbh 12.5 cm+ to a 10-cm diameter inside-bark top and a 30-cm-high stump, excluding decay as estimated from Ministry of Forests loss factors. Dead potential and veteran trees were not included in the volume estimates.

The audit volume samples were then compared to the inventory volumes to test the validity of the current inventory .

Revised results

Results of the statistical analysis of the inventory audit for volumes at a 12.5 cm+ dbh utilization level are given in Table 1.

TABLE 1. Statistics for the audit volume and inventory volume estimates at 12.5 cm+ dbh utilization for the Mackenzie TSA

	Audit volume estimate	Inventory volume estimate
Number of samples	47	47
Mean (m^3/ha)	187	207
Coefficient of variation (%)	52	42
Standard error (m^3/ha)	14.1	12.7
Sampling error (%) at 95% confidence level	15.2	12.3
95% confidence interval (m^3/ha)	159–216	182–233

Correlation: 0.694 (p-value < 0.001)

Ratio of audit volume to inventory volume: 0.90

The correlation coefficient of 0.694 for the audit and inventory estimates for mature volume indicates a good relationship among the individual samples. There is a 20 m^3/ha difference between the means of the audit volume (187 m^3/ha) and the inventory volume (207 m^3/ha). Sampling errors (at the 95% confidence

level) for the audit and inventory volume estimates were 15.2% and 12.3% respectively.

The ratio of mean audit volume to mean inventory volume was 0.90. A two-sided paired-sample t-test showed that there was no significant difference between the estimates of mean volume per hectare for the audit and the inventory.

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (operable areas). The audit results were post-stratified based on this approximation. The results of the inventory audit for samples in the operable forested areas in the TSA are shown in Table 2.

Twenty-one of the samples were in inoperable forested areas. Because of the high variability and restrictive nature of conclusions associated with this small sample, volume estimates from inoperable forested areas are not shown.

TABLE 2. Statistics for the operable audit volume and inventory volume estimates at 12.5 cm+ dbh utilization for the Mackenzie TSA

	Audit volume estimate	Inventory volume estimate
Number of samples	26	26
Mean (m^3/ha)	222	251
Coefficient of variation (%)	46	35
Standard error (m^3/ha)	19.8	17.3
Sampling error (%) at 95% confidence level	18.4	14.2
95% confidence interval (m^3/ha)	181-263	215-286

Correlation: 0.699 (p-value < 0.001)

Ratio of audit volume to inventory volume: 0.88

The correlation coefficient of 0.699 for the 26 samples located within operable forested areas indicates a good relationship among the individual samples. The mean audit volume was 222 m^3/ha and the corresponding inventory volume was 251 m^3/ha. The difference between these two estimates was not statistically significant. Sampling errors for the audit volume and inventory volume estimates in the operable forested area were 18% and 14% respectively.

Discussion and conclusions

The results of the inventory audit for the Mackenzie TSA suggest that the current inventory of mature volume (completed between 1965 and 1982) is statistically acceptable. Subsequent analysis of post-stratified data also shows a similar level of acceptability in the operable forested area.

It is recommended that the results of this study be used to assist in determining field data entry levels for the ongoing pre-inventory assessment program.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building block around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities.

bias: The quality of a measurement device or procedure that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of zero indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height

(1.3 metres above the point of germination), to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable: Refers to areas having merchantable timber that cannot be harvested economically using current harvesting technology because of some physical barrier (such as a hanging valley), and to areas containing small patches of overmature timber surrounded by large areas of young stands.

mean: The average value of a set of observations.

public sustained yield units (PSYU): A portion of a TSA. An area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit, and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds, and tree farm licences.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as the basis for deciding whether to re-inventory or update the current inventory, and to doc··ent the existing inventory, maps, and photos t··· ort the execution of the re-inventory or ··te if required.

ratio estimate: The ratio between two ··rent estimates.

representative: The quality of a sample ··ng the same characteristics as the population from ·ich it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: The technical process of amalgamating land management information into computer systems that predict the amount of timber available for harvest over given time periods.

timber supply area (TSA): An integrated resource management unit established in accordance with Section 6 of the *Forest Act*.

tree farm license (TFL): An integrated resource management unit established in accordance with Section 28 of the *Forest Act*.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volumes (net decay) and diameters at four utilization levels using stand height, age, and density. The air approach, which uses crown closure (CC) as the density measure, is currently implemented.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, B.C. Ministry of Forests, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7
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